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## SCATTERING OF A WAVE BEAM BY INHOMOGENEOUS ANISOTROPIC CHIRAL LAYER

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### ABSTRACT

Wave beam scattering from uniaxial unidirectionally inhomogeneous lossy chiral layer is studied using Fourier spectral method. As an example reflection of the H-polarized Gaussian beam is analyzed and distinctive features of the reflected beam field distribution is revealed and graphically illustrated.

### INTRODUCTION

Layered chiral media with unidirectionally inhomogeneous parameters are potentially attractive for optoelectronic and microwave device design, e.g. for the fabrication of matching layers, which simultaneously transform the EM wave polarization. Plane wave scattering from layered chiral structures has been investigated in detail by many authors [1, 2]. In practice, however, electromagnetic fields of real sources and apertures substantially differ from plane waves but as a rule can be represented as partial plane waves continual superposition – wave beams [3, 4]. In the present study we consider the problem of the H-polarized Gaussian wave beam scattering from unidirectionally inhomogeneous anisotropic chiral layer.

### FORMULATION OF THE PROBLEM

Let us consider H-polarized Gaussian beam obliquely impinges on uniaxial chiral layer with material parameters varying with depth (Figure 1). The axis  $z$  of the global Cartesian coordinate system  $xyz$  is coincident with the axis of layer stratification. Material parameters of the slab are described by the second rank tensors  $\hat{\varepsilon}, \hat{\mu}, \hat{\kappa}$ , that relate the components of the time harmonic,  $\exp(-i\omega t)$ , plane wave electric displacement  $\vec{D}$  and magnetic induction  $\vec{B}$  with fields  $\vec{E}, \vec{H}$

$$\vec{D} = \hat{\varepsilon} \cdot \vec{E} + \hat{\kappa} \cdot \vec{H}, \quad \vec{B} = -\hat{\kappa} \cdot \vec{E} + \hat{\mu} \cdot \vec{H}. \quad (1)$$

Due to the uniaxial symmetry material tensors can be written in the form

$$\hat{\eta} = \eta_{\perp} \hat{I}_{\perp} + \eta_{\parallel} \vec{z}_0 \vec{z}_0,$$

where  $\hat{I}_{\perp} = \vec{x}_0 \vec{x}_0 + \vec{y}_0 \vec{y}_0$ , and

$$\eta_{\perp, \parallel}(z) = \eta_{\perp, \parallel} f(z), \quad \eta = \varepsilon, \mu, \kappa.$$

Function  $f(z)$  specifies inhomogeneity profile of the slab. Magnetic field of the incident wave beam is polarized along the  $x$  direction,  $\vec{H}^{inc} = H_x^{inc} \vec{x}_0$ , with spatial magnetic field distribution represented as a continual sum of partial plane waves over spectral

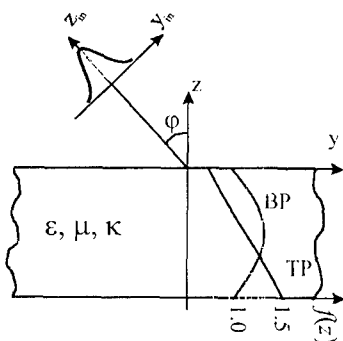


Fig. 1. Geometry of the problem



parameter  $k_{in}$ ,

$$H_x^{inc} = \int_{-\infty}^{\infty} U(k_{in}) \exp i(k_{in} y_{in} - \gamma_{in} z_{in}) dk_{in}. \quad (2)$$

In Eq. (2)  $\gamma_{in} = \sqrt{k_0^2 - k_{in}^2}$ ,  $k_0 = \omega/c$ . Physically  $k_{in}$  and  $\gamma_{in}$  determine the components of a partial plane wave vector in the local basis set  $x_{in} y_{in} z_{in}$ . The spectral density  $U(k_{in})$  is assumed to be  $U(k_{in}) = \exp(-b^2 k_{in}^2/4) H_n(k_{in} b/\sqrt{2})$ , where  $2b$  is a beam width,  $H_n(\cdot)$  is Hermite polynomial of the  $n$ -th order [5]. In the frames of spectral method the scattering beam field distribution is represented in the Fourier integral form

$$H_x^r = \int_{-\infty}^{\infty} R_{ss}(k) U(k_{in}) \exp i(ky + \gamma z) dk_{in}, \quad (3)$$

$$E_x^r = \int_{-\infty}^{\infty} R_{ps}(k) U(k_{in}) \exp i(ky + \gamma z) dk_{in}, \quad (4)$$

where  $k$  and  $\gamma$  determine the components of a partial plane wave vector in the global coordinate system,  $R_{ss}$  and  $R_{ps}$  are the partial plane wave reflection coefficients. The  $R_{ps}$  term describes EM wave polarization transformation due to chirality of the slab. The reflection coefficients  $R_{ss}$  and  $R_{ps}$  are obtained numerically using the finite-difference algorithm [2].

## NUMERICAL RESULTS AND DISCUSSION

As an example we consider the slab with material parameters  $\varepsilon_{\perp} = 2.1 + 0.2i$ ,  $\varepsilon_{\parallel} = 5.6 + 0.2i$ ,  $\mu_{\perp} = 1.10 + 0.1i$ ,  $\mu_{\parallel} = 1.22 + 0.1i$ ,  $\kappa_{\perp} = -0.01 + 0.2i$ ,  $\kappa_{\parallel} = -0.01 + 0.2i$ , homogeneous and inhomogeneous with barrier and transitional profiles  $f(z)$ , which are schematically indicated in figure 1 as "BP" and "TP" respectively.

Figure 2 delineates how the changes of the material inhomogeneity profile affect the partial plane wave reflection coefficient module and phase. The main interesting feature is the Brewster angle and phase steepness behavior. It should be noted that the crucial role plays chirality parameter  $\kappa_{\perp}$ : increasing of  $\kappa_{\perp}$  leads to smoothing of the sharp variation of the reflection coefficient phase and module and to shifting of the Brewster angle position in the incidence angles scale. Scattering beam field distribution in the near zone ( $z = 0$ ) is shown in the Figures 2b and 2c. Gaussian beam of the width  $4\lambda$  with spectral density described by the first order Hermite polynomial incident on the slab at the angle  $\varphi = 46.8^\circ$ . Fig. 2b illustrates strong distortions of the beam shape – reflected beam splitting (occurred in the copolarized component) and the beam axis displacement. These distortions are caused by sharp variations of the partial plane wave reflection coefficient module and phase near the critical angle. In the case of inhomogeneous slab with described profiles reflected beam splitting is absent, but beams axial displacement, proportional to the first derivative of the reflection coefficient phase, is still substantial. In the far field zone the reflected beam spatial distribution becomes smoother.



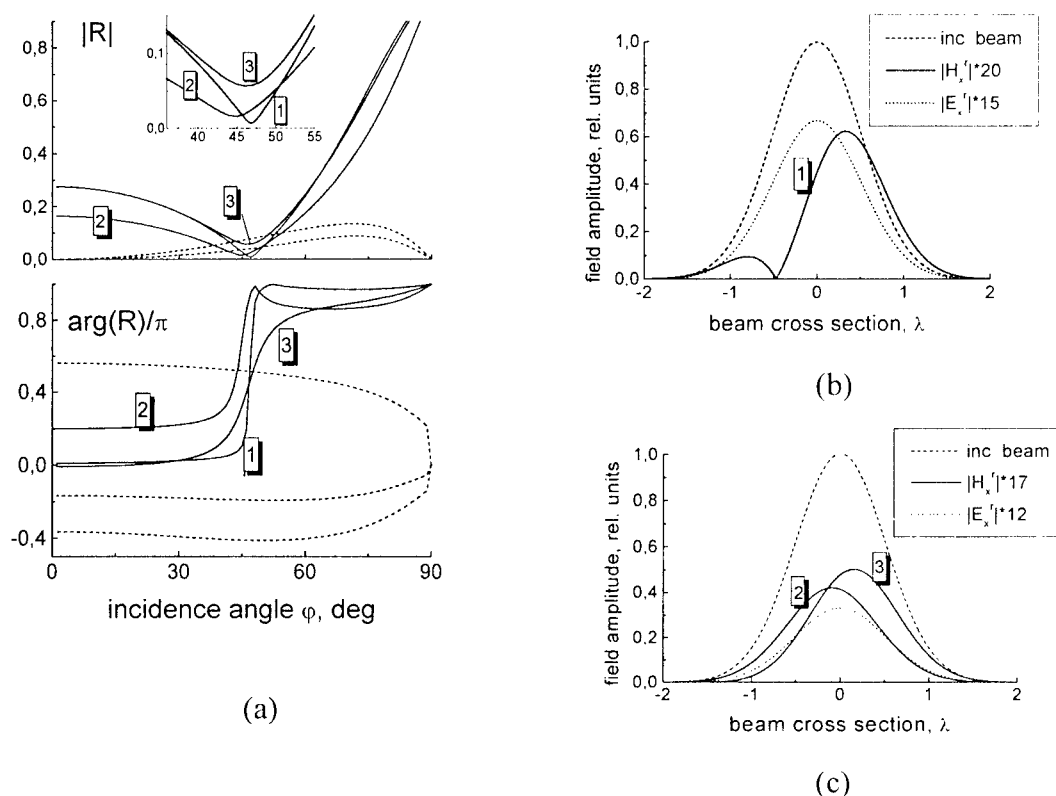


Fig.2. Partial plane wave reflection coefficients (2a) and scattering beam field distribution (b,c) in the near zone. Curve 1 – homogeneous layer, 2 – inhomogeneous layer, barrier profile, 3 – transitional profile. For fig. 2a solid curves –  $R_{ss}$ , dashed curves –  $R_{ps}$

## CONCLUSION

The problem of Gaussian wave beam scattering from anisotropic lossy inhomogeneous chiral layer is solved using spectral Fourier method. It has been shown that for the case of H-polarized beams strong distortions – reflected beam splitting and beam axis displacement – dependent on the material parameters inhomogeneity are occurred. Results of the undertaken investigation can be applied in the theory of the wave beam shaping control and remote sensing of chiral media.

## REFERENCES

- [1] Lindell I. V., Sihvola A.H. // IEEE Trans. Antennas Propagat. – 1995. – Vol. 43, № 12. – P. 1397 – 1404.
- [2] Zhuck N. P., Malyuskin A.V., Shulga S. N. // Radiotekhnika i Electronika. – 2000. – V. 45, № 6. – P. 654 – 661.
- [3] Arnaud J.A. Beam and Fiber Optics. N.Y.: Academic, 1976.
- [4] Brekhovskiy L. M. Waves in Layered Media. Moscow, 1957.
- [5] Goncharenko A. M. Gaussian Light Beams. Minsk, 1977.